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Integrated model for reverse logistics management of electronic products and components

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Abstract

In August 2010, it was sanctioned a National Solid Waste Policy (PNRS - Política Nacional de Resíduos Sólidos) that features innovations as the Reverse Logistics which determines that manufacturers, importers, distributors and retailers must perform the collection of used packaging. Thus, what is the actual difficulty of companies in meeting the requirements of the PNRS? The purpose of this article is to propose a management model that uses Information and Communication Technology (ICT) and the WEB to assist in the integration of all stages of Supply Chains of electronic products and their components. It is an applied research with a qualitative approach where, after a critical analysis of the PNRS, a literature review was conducted involving the state of the art in Supply Chain Management, the ICT and the development of Enterprise Resource Planning (ERP) systems. The application of the proposed model in supply chains of electronic appliances through environmental protection and a direct interaction with the ultimate consumer offers enterprises a competitive advantage and can minimize financial losses associated with fines and violations. The following stages of this research include the development of a WEB portal with the proposed model and its availability for government use, thus enabling its practical application trials.

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Keywords: Reverse Logistics; PNRS; Information and Comunication Technology; Integrated Management Model; 3rd generation ERP.

1. Introduction

In August 2010, legislation concerning the National Solid Waste Policy (PNRS - POLÍTICA NACIONAL DE RESÍDUOS SÓLIDOS) was introduced by the President of Brazil. It is the regulatory framework in solid waste management that distinguishes what can be recycled and what is not prone to reuse.

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Siena [1] indicates the reduction in solid waste generation as one of the potential aspects for sustainability assessment. Thence, the following question arises from the presently described research: what is the actual difficulty of companies in meeting the requirements of the PNRS?

The PNRS features innovations such as Reverse Logistics (RL) which determines that manufacturers, importers, distributors and retailers must perform the collection of used packaging. Products as pesticides, batteries, tires, lubricating oils, and all sorts of lamps, light bulbs and electronics were included in this system.

A few goals and the proposal of the PNRS are summarized as follows [2]:

- Its aim is the generation, reduction, reuse and treatment of solid waste, as well as an environmentally appropriate final disposal of non-reusable items, a reduction in the use of natural resources (water and energy, for example) in the production process of new products, intensification of environmental education actions, increased recycling in the country, promotion of social inclusion through employment and income generation for recyclable material collectors.
- Its proposal is to establish the principle of shared responsibility through products' life cycle, including manufacturers, importers, distributors, traders, consumers and public urban cleaning and solid waste management servants, i.e. it proposes shared assignments, both for public and private institutions, as well as the society in general. One of the fundamental principles of the PNRS is called reverse logistics which constitutes a set of actions to facilitate waste return to their rightful generators, so that they are treated or recycled into new products.

Among the major challenges imposed to manufacturing companies by the PNRS, the third, fourth, fifth, sixth and eighth sections of the thirty-third article stand out, which specify the disposal of pesticides, their residues and packaging; batteries; tires; lubricating oils with their residue and packaging; fluorescent, mercury and sodium vapor, and mixed-light lamps; electrical and electronic products and their components. In these sections, it was determined that:

- "manufacturers, importers, distributors and traders [...] are due to take all necessary measures to ensure the implementation and operationalization of reverse logistics system under their charge";
- "Consumers must make the return of used goods to traders and distributors of products and their packages...";
- "Traders and distributors must make the return of goods to manufacturers or importers of products and packages...";
- "Manufacturers and importers will have to provide an environmentally adequate site for collected or returned products and packaging, so that non-reusable items are environmentally and appropriately disposed...";
- "With the exception of consumers, all those belonging to reverse logistics systems will have to make available and updated to the competent municipal body and other authorities, detailed data on the implementation of actions under their responsibility".

The markets instability and an intense competition among companies are becoming a major challenge for business management [3]. The greatest challenge that companies have faced in order to meet the PNRS requirements and maintain a competitive position in business is to establish a link between consumers, customers and suppliers in order to track their products along the supply chain. Despite the paradigm shift of this new generation of Enterprise Resource Planning (ERP), third-generation, to improve supply chain management, their use is still limited due to the need of changing paradigms involving sensitive data exposure on the Internet. Many companies prefer to keep using the traditional ERP systems that are based on the way businesses were structured in the last couple of decades.

An investment in the implementation of current models of Management Systems is substantial and ends up diverting efforts of areas that really matter in the company. The use of the new generation of ERPs, third-generation, not only would help in meeting the legislation, but also could allow the optimization of enterprise resources, such as time, finances and staff. Thus it can be observed that the ERP system which was originally a type of system produced by renowned software companies and used only by large companies, started, a few years ago, to turn its attention to smaller companies [4].

"The revolution of information technology is a historic event because it introduced a discontinuity pattern into the material foundations of economy, society and culture" [5]. At present, due to communication technology, society is going through a historic moment in information technology. Information systems linked through hypermedia (WEB), more specifically the Web-Services, are radically changing the daily lives of people and the way businesses are conducted. High-speed Internet (broadband) is available in most small and midsize companies, which helps in the inclusion of these companies in the world of digital communication, enabling the implementation of electronic communication systems.

The overall objective of this article is to propose a management model, using information and communication technology (ICT) and the WEB, in order to assist in the integration of all stages of the supply chain of products belonging to the 32nd article of the PNRS, more specifically electrical and electronic appliances and their components.

To achieve this objective, some specific goals were set:

- Conducting a literature review involving the state of the art in supply chain management (Supply Chain Management-SCM), their definitions and objectives, the ICT and the development of their systems, from the traditional ERPs, followed by the second generation ERPs up to the latest systems called as third generation ERPs;
- Proposing an integrated model for managing the RL in the disposal of electrical and electronic products and their components at the end of their lifetime.

This work seeks to present a well-defined view on this approach. The first boundary is placed on the study to be directed to the PNRS, a second one refers to the RL study of electrical and electronic products and their components, and a third one refers to the model being limited to using the WEB integrated to third-generation ERPs.

To meet the objectives of this work, the used research methodology was structured around four pillars: its nature, approach, objectives and technical procedures.

In this work, it was opted for an applied research in nature which, according to Fulgencio [6], is an original research designed for acquiring new knowledge. It is, however, primarily conducted towards a specific practical objective. Moreover, still according to Fulgencio [6], it is carried out to determine the possible uses for the basic research findings to define new methods or ways to achieve a specific and predetermined goal.

The article is going to have a qualitative approach because, according to Gressler [7], it is used with the aim of describing the complexity of a given problem, not involving manipulation of variables and experimental studies. Within such broad concept, qualitative data also include information that cannot be expressed in words, such as paintings, photographs, drawings and films. Thus, in accordance with Malhotra [8], a qualitative research provides a better view and understanding of the context of the problem, while a quantitative research seeks to quantify the data, and it typically applies some form of statistical analysis.

It was opted for a descriptive and exploratory research in the development of this work because, according to Santos [9], descriptive-exploratory design researches have the primary goal of providing a broad view of the selected theme, being an exploratory research and not requiring data collection. As for the technical procedures, it was initially chosen a literature review, followed by the management model proposal.

This work is organized into four sections. Section 2 presents the theoretical framework, Section 3 describes the proposed model, and Section 4 draws the conclusions followed by the references.

2. Theoretical Framework

This section briefly explains the SCM, its definitions and objectives, the ICT and the development of its systems since the traditional ERPs, followed by the second generation ERPs up to the latest systems called as third generation ERPs.

2.1. Supply Chain Management (SCM)

The reality experienced by enterprises currently requires the integration of all supply chain through its

management, which covers the entire flow of product transformation [10]. In addition, Sellitto [11] states that SCM should not only be focused on logistic processes, but on all business processes that are related to the ultimate customers' requirements. Thus, it can be considered an important model to achieve competitive advantage, aiming to add value in the view of customers and other stakeholders [12], including the reverse logistics of products and packaging imposed by the PNRS.

In this article, the supply chain branches from the ultimate consumer to the basic raw material, but its management occurs only from a company named "Focus Company", as shown in Fig. 1.

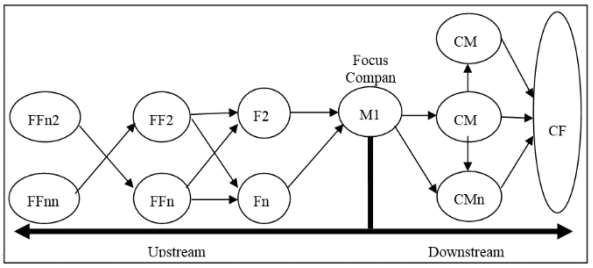

Fig. 1. Supply Chain of the Focus Company. Source: [13].

A proper management of the supply chain enables an optimized production offering the ultimate customer the right product, in the right amount. The goal is to reduce costs throughout the chain, taking into account the customers' requirements [14]. For such a purpose, several tools can facilitate the SCM, as the Information Technology (IT), which can be a strong ally to integrate all parts of the process in real time. In recent years, it strengthened a lot, however, so that there is speed and safety in relationships, the use of various support systems is needed, such as the ERP [15].

In the 80's and 90's, manufacturing organizations have concentrated efforts on departmental management change into process management. At the end of the 90's, a new paradigm emerged where business processes have become the supply chain processes and no longer belonging exclusively to the organization.

The change of individual management into managing the relationships between the members of a supply chain is required for integrating the business processes with the supply chain, creating a value system [11]. In the face of this need for integration, Martins [16] highlights the model of Cooper [17], which has three elements: the business processes, components management and supply chain structure. Lambert [18] states that the eight-business macro processes correspond to a long process of development of the author himself started in 1992. Of these processes, customer relationship and demand management has been considered as the core for an efficient SCM.

According to Ballou [19], the dependency of organizations reflects the difference in power among them, because an organization has a certain amount of power in relation to other organizations as it holds the resources needed by them, or as it reduces its own dependency on them through using these resources to its own advantage. The power wielded in supply chain mutates over time. For instance, much of the manufacturers' power was conferred on retailers in the past decade in light of exercise in consumer preference.

Industries are affected by various risks of shortages and interruption that may incur in various ways and be influenced by several factors. These factors vary from a geopolitical instability in a supplying region to more specific factors, as suppliers strikes, however, the risk of shortages is usually related to the power exercised in jail and, consequently, to the customer relationship management process.

2.2. Sustainability in the Supply Chain

According to Lages [20], the term sustainable development was coined during the World Commission on Environment and Development, established by the UN in December 1983, and the publication of the final report – known as Brundtland report – in 1987. Sustainable Development is defined as a

balanced economic, political, social, cultural and environmental model, which satisfies the needs of current generations without compromising the ability of future generations to come in meeting their own needs [21].

In manufacturing companies, after the recognition of quality as a generator of competitive advantages, management systems have been created to address other important issues, such as the environment. The most integrated performance of supply chains can promote environmental management and provide important opportunities for business development in line with sustainability [22].

In the view of Oliveira [23], a business must be evaluated not only in terms of financial results, but also regarding their impact on the economy as a whole, environmental awareness and social responsibility, which correspond to the three pillars of the *Triple Bottom Line* (3BL). Kleindorfer [24] highlights that one of the symptoms of the current pressure for sustainability is the 3BL movement concerning the relationship among profit, people and the planet acting on culture, strategies and operation of enterprises.

According to Ballou [20], 3BL initiatives must be aligned with the strategic guidelines of organizations to ensure an effective implementation in the three basic dimensions of sustainability: economic, environmental and social ones. The concept and practices of the 3BL are illustrated in Fig. 2.

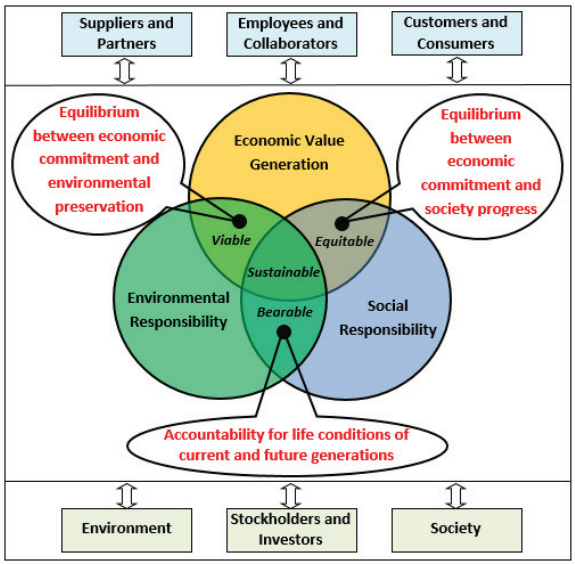

Fig. 2. The 3BL (*Triple Bottom Line*). Source: [22]; [20].

2.3. Information and Communication Technology - ICT

According to Pires [25], the development of ICT has considerably enhanced since 1990 to present date, and the Internet is becoming something quite revolutionary. Kleindorfer [6] states that evolution and improvement of SCM models demanded, consequently, a greater necessity of using ICT systems as support to their operation.

The ICT has shown its importance in generating benefits in terms of efficiency and transformation, affecting individuals, functional units and the organization as a whole. The evolution of ICTS has gone beyond automation, generating organizational implications and providing people more accurate information, basis for improving the decision-making process and the development of products and services. The ICT has a relevant role as a source of competitive advantage, not only for aiding managers in making decisions and taking action, but also by adding value to products and services of the organization.

Before the introduction of computer systems in the production process, management techniques were painful, slow, and by hand. The advancement of information technology allowed the use of computer systems by companies to support their activities. Generally, in each

company, several systems have been developed to meet the specific requirements of its various business units, plants, departments and offices. The information was divided between the different systems. The main problems of this fragmentation of information were related to the difficulty of conciliating the information and the inconsistency of redundant data stored on more than one system.

MRP is an acronym that stands for Material Requirement Planning. It had emerged in the 70's and only addressed the needs of materials. It is a computerized inventory and production control system that optimizes management to minimize costs while maintaining adequate materials and levels that are required for the production processes of the company. From the 80's, systems and materials planning concepts have been developed and integrated with other parts of the company. With this developed version of the MRP, the MRP II was created [6].

The MRPII (*Manufacturing Resources Planning*) works seamlessly in the supply chain, once demand forecasting is critical, making it a great advantage over the MRP, which only handles the resupply of materials. Capacity is another upgrade obtained by the MRPII, i.e. the MRPII takes into account the capacity of the plant, equipment, facilities and available work force, generating the need for material, i.e. raw material and finished product [6].

The ERP was created in the 90's, which is a system that synchronizes, integrates and controls the processes of a company in real time by the use of advanced information technology that was designed within the concept of a single Information System for the whole company.

Among the explanations for the need of this tool are the competitive pressures suffered by companies that were forced to seek alternatives for reducing costs and differentiation of products and services. In the light of this context, companies have been forced to review their processes and the way they work and recognized the need to better coordinate their activities within their value chain to eliminate waste of resources, reducing the cost and improving response time to the changing market needs.

The first generation ERP arose to automate key management processes. It is a desktop model that essentially gave support to routine transactions and its ability to manage administrative activities as payroll, inventory and order processing was insuperable. However, it did not give the support needed in the continuous planning of the supply chain.

According to Teixeira Jr. [28], the APS software (Advantage Planning and Scheduling) is a decision-making support system that is not intended to replace production managers, but to maximize their role through sophisticated user interfaces, allowing any kind of change in formulated plans and making adjustments viable when considering the peculiarities of use in each industry. These features indicate that the APS software is a new technological frontier for an efficient production management. However, only large companies have access to this system because they can afford its acquisition and implementation, and because it involves technology and international delivery.

This new model should incorporate functionalities related to SCM where, after the integration of the internal processes of the company, every chain will be able to be integrated. These resources rely heavily on the internet. With the evolution of globalization, commercial relations know no bounds, thus the Internet becomes an extremely cheap and feasible means for this type of application.

This paradigm shift is not simple and the development into this new generation of ERP applications, though necessary, will require some time to be improved. This new model will incorporate the functions of the conventional ERP associated with the APS, however, changing into a *Cloud Computing* environment (cloud computing) , which is characterized by not requiring an internal IT structure, thus the concern about expenses to keep the server within the Enterprise is not relevant [29].

To be considered a third generation ERP where the possibility of use is not going to be restricted to large companies, some questions need to be answered:

1 - "Using and Learning" instead of "Learning to Use". The ERPs will need to be as intuitive as the other cloud platforms (Facebook, Gmail, Skype, etc.) in order to attend the new generation "Y".

2 - "Compatibility" should be an integral part of these ERPs where they must provide, through APPs, access to

any digital platform (smartphones, tablets, etc.).

3 - "Seamless Integration", full integration between companies of a given supply chain becomes the main difference in using a popularized business management platform.

The Internet was created in 1969, under the name of ARPANET, a result of a project to interconnect the computers of research, governmental and educational institutions. In 1994, the Netscape arose, which expanded access to e-commerce and served as a precedent for the development of low-cost software to consumers [26]. B2B (Business to Business) refers to the business transaction between two companies over the internet [6] [27] claims that once e-commerce is integrated to the B2B, the way of operating supply chains changes. According to Scavarda, Ribeiro and Batalha quoted by Fulgêncio [6], security is one of the fundamental aspects of IT and is defined as confidentiality, integrity and availability.

2.4. Using the ICT for Identification – the Barcode

The barcode is nothing more than a graphical representation of the sequence of digits that is printed just below it. The advantage of the bars is that they can be identified quickly and without any risk of error with hand-held devices, as the optical scanner used by grocery cashiers [30]. According to Terra [31], barcodes are the most effective means to identify quickly products, which is by decoding them with a scanner through a computer.

According to Terra [31], there are four types of barcode scanners and each uses a different technology to scan and decode them: contact wand scanners, standard scanners, lasers scanners, CCD scanners, and scanners with cameras, described below:

- Contact wand scanners consist of a light source and a photodiode that are on the tip of a pen or similar object. For the scanning, the tip should read the barcode with a linear and delicate movement. The photodiode measures the intensity of the reflected light from the light source and generates a wave that is used to measure the size of the bars and gaps in the code. The dark bars of the bar code absorb light and the white gaps reflect light, thus forming the wave that is reflected back to the photodiode. This kind of wave is decoded by the scanner in a similar manner to the decoding of dots and stripes of the Morse code.
- Laser scanners work in the same way, except that contact wand scanners use a laser as light source and typically use a mirror or prism to direct the beam over the whole surface of the barcode. A photodiode is responsible for measuring the intensity of the light reflected from the code. In both readers, the light emitted by the reader has a determined frequency and the photodiode is designed to detect this same frequency.
- CCD Scanners (Charge Coupled Device) use an array with hundreds of tiny light sensors lined up in a row in the scanner's tip. It is as if each sensor were a photodiode, which measures the intensity of received light. Each individual light sensor in the CCD scanner is very small and, as there are hundreds of other sensors lined up, it becomes a pattern, which is identical to the standard barcode. The most significant difference between a CCD scanner and a contact wand scanner is that the former measures the ambient light reflected by the barcode while the latter emits its own light to make measurements.
- The fourth and most modern type is the scanner that uses a small video camera to capture the image of the barcode. The reader then uses sophisticated digital image processing techniques to decode the barcode. Video cameras use the same technology of CCD readers except that, instead of having a single line of sensors, a video camera has hundreds of rows arranged in a two-dimensional array to generate an image.

Ever since its creation, for over 35 years, the barcode has changed the lives of retailers and consumers. This old gadget was the starting point for other data decoding systems, like Identification by Radio Frequency (Radio Frequency Identification - RFID) and the Quick Response Code (Quick Response – QR code). Versa [32] defines the need for an appropriate scanner and the limitation in data entry as being the greatest drawback of using the barcode, due to the one-dimensional and sequential feature of the model, that is, each character is equivalent to a sequence of bars with different widths and spacing. The longer the message inserted in the code is, the greater its width becomes, which obviously limits its use. Nowadays, bar codes are divided into two groups, the one-dimensional and two-dimensional ones, with emphasis on QR *Code*.

Created in 1994 by the Japanese company Denso-Wave, the QR *Code* is a two-dimensional (2D) code, shown in Fig. 3, which can be scanned directly by a cell phone camera (even with low-resolution images, taken by digital cameras in VGA format) and interpreted by apps developed by the manufacturer. It stores up to seven thousand letters and four thousand numbers, against only 20 characters of the one- dimensional barcode [32]. Currently, the QR code is used by the print media (magazines, pamphlets, billboards and others) and can be a tool of great assistance in handling and storing products.

Fig. 3. QR Code (Quick Response Code)

One of the advantages of the QR Code is that it eliminates the need to type WEB addresses: it is only necessary to launch the application and point your cell phone at a QR Code for the additional content to be displayed in the reader or Web browser.

3. Proposed Integrated Model of Reverse Logistics

The PNRS, published in 2010, imposes a series of duties for organizations to play their social role as regards environmental protection. In general, companies have great difficulty in complying with these guidelines and end up subjecting themselves to fines.

The purpose of this section is to present a proposal for an integrated management model of RL of electrical and electronic products and components to meet the PNRS requirements in an operational manner, without the demand of disproportionate costs for organizations.

3.1. Structuring the Proposed Model

This model has been designed for using WEB concepts and principles in order to integrate final consumers, distributors, retailers, and cooperatives with manufacturers/importers in a manageable manner by the government.

Fig. 4 illustrates the basic structure of the proposed model, which aims to be a facilitator in the operation and management of the PNRS. The model's basis is the creation of a centralized government portal so that all links in the supply chain use it as a communication interface in order to meet the guidelines set forth by the PNRS, and also, through an act of citizenship, to ensure an adequate disposal of electrical and electronic products and their components. It is essential that, once it is deployed, a broad and immediate interaction occurs in order to ensure the credibility of the model.

Fig. 4. Structure of the Proposed Model.

3.2. Operationality of the Proposed Model

According to Fulgencio [6], when all participants of a SC are integrated and they operate as a single entity, harmonizing supply and demand throughout all links, the result should be performance improvement. Comments on the activities included in the proposed model are as follows:

- Interaction between Government Agencies and the PNRS Portal

It is due to government agencies to publish and maintain the PNRS portal, with the aim of setting a model where the other members of the supply chain can interact properly.

- Interaction between Manufacturers, Importers and the PNRS Portal

It will be required, through the regulation of the PNRS, that companies must know the address of the portal site where they would register ways and suitable locations for the disposal of electrical and electronic products that are manufactured by them. Through access with digital certification, these organizations would keep data updated in the specific address, and make a two-dimensional barcode (QR Code) and the WEBSITE link available, both on the product and its respective packaging.

- Interaction between Cooperatives and the PNRS Portal

Cooperatives and NGOs would also have access to the PNRS in order to assist and include alternatives for an adequate disposal and try to change the reality where. According to [33], the presence of garbage recycling cooperatives in this process is still moderate, which is probably due to their own poor management and infrastructure. Conceição [33] considers that inorganic waste recycling work is being carried out in an amateur and informal way by garbage collectors, thus the present model would have, as one of its goals, to professionalize the management of this process in order to to get rid of the large volume of junk e-mail to be discarded.

With the indication of addresses and way of sending junk e-mail to ultimate consumers in the PNRS portal, unused electronic materials could be sent, thus seeking environmental balance.

- Interaction between Ultimate Consumers and the PNRS Portal

With the QR *Code* imprinted on products and packaging, as illustrated in Fig. 4, ultimate consumers would simply have to run the scanning application (any scanning QR *Code* application) and point the phone at a QR Code on a product or packaging so that the content available in the PNRS Portal becomes visible on their screen through an internet browser. In this way and associated with a program to raise awareness, ultimate consumers could participate more actively and without any great efforts in the disposal of their electronic waste.

4. Conclusions

Operating in a globalized and competitive environment, manufacturing companies have had difficulty in implementing a SCM model, which is able to meet their needs in order to ensure the development of sustainable competitive advantages and meet the requirements related to the PNRS. Ultimate consumers have difficulty in finding information to help them dispose of their electrical and electronic waste.

The possible application of the proposed model in the supply chain of manufacturing and importing enterprises of electrical and electronic products leads to a result that, by protecting the environment and a direct interaction with the ultimate consumer, would generate competitive advantages in addition to mitigating losses through fines and violations, due to non-compliance with the according legislation. The model also showed an alignment of possible results with the *Triple Bottom Line*, ensuring economic prosperity and increased competitive advantage for the involved companies, coupled with the search for environmental preservation and respect for people.

The proposed model seeks to maximize the benefits of each of the studied systems, while at the same time minimizing the limitations presented by them, thus offering simple tools that meet the needs of managers in the pursuit of success for their businesses.

Since this work is just an early effort in the pursuit of competitive advantages gain for manufacturing organizations and environmental protection, new scientific studies can and should open new opportunities, improving its performance and broadening the range of application of the model through process simulations and case studies, besides analyses of its popularity with ultimate consumers in the process.

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